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**DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION**  
**AERONAUTICAL RESEARCH LABORATORY**  
**MELBOURNE, VICTORIA**

**Aircraft Materials Report 124**

**POLYALPHAOLEFINS: A NEW IMPROVED COST  
EFFECTIVE AIRCRAFT RADAR COOLANT**

by

**MICHAEL A. STROPKI**

Approved for public release

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**POLYALPHAOLEFINS: A NEW IMPROVED COST  
EFFECTIVE RADAR COOLANT**

by

MICHAEL A. STROPKI\*

**SUMMARY**

*The use and potential problems associated with silicate ester (Coolanol) dielectric coolants in US military applications such as aircraft radar and missile systems are highlighted. These fluids have caused significant and sometimes catastrophic problems due to their hygroscopic nature and subsequent formation of flammable alcohols and silica gel. In some of the more advanced stages, a gelatinous precipitate has caused component malfunctions such as electrical arcing, filter clogging, and fires. Extensive and costly fluid monitoring procedures have brought the malfunction under control, but this has not eliminated the problem.*

*The US Air Force and Navy have investigated the replacement of these silicate-ester-based fluids with a hydrogenated polyalphaolefin-based (PAO) fluid in order to solve these material system problems. This report includes a brief historical perspective of silicate-ester related problems, the advantages and disadvantages of PAO, specific US Air Force/Navy aircraft system flight test programs, and current status of the US PAO conversion.*



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## 1. INTRODUCTION

The problems associated with the use of silicate ester fluids in radar coolant applications first surfaced in the 1970's in US Navy aircraft and missile systems. The problems were linked to decomposition of the silicate ester fluid in the presence of moisture and high electrical stresses which led to the formation of silica gel that deposited on electrical components. This process also formed an highly flammable alcohol by-product which reduced the flashpoint of the fluid. This finding prompted the Navy to begin a monitoring system for water and ionic contamination in systems using silicate ester coolants. NADC was directed to investigate an improved fluid which was less susceptible to degradation(1). At this time, the Air Force had not experienced the same problems due to operations under less humid environments and use of a less reactive silicate ester.

After the loss of a US Navy aircraft in 1978 attributed to a silicate ester fire, an effort to find a viable solution to the problem was initiated. Reports that followed field investigations stated that when certain avionics were open for inspection, seventy percent were found to be grossly contaminated with particulate matter generated from silicate ester fluid degradation(1). Some of the units containing silicate ester fluid with undissolved water had contained evidence of massive arcing and case damage. These problems, along with the appearance of a white silica gel-type of material and lowered flash point, initiated a more aggressive search for a superior material.

Within the next three years, other material problems related to silicate esters surfaced within both the Air Force and Navy (1,4). New evidence of a "black plague", which was the formation of black and gray solid particles, was reported on electrical circuit boards and at high voltage connections such as the 18KVDC 013 filter network terminal of F-15 radar transmitters. Although investigations did not conclude that the black and gray particles found in contaminated systems were formed before the arcing or as a by-product of the high energy arcs, the moisture sensitivity of silicate esters significantly contributed to the problem. These findings, along with more recent evidence have provided the incentive for both US services to begin an accelerated assessment of the new polyalphaolefin (PAO) material in a number of aircraft radar systems.

Due to the commonality of many aircraft and aircraft systems within the US Air Force and Navy, many materials used by the two services are commonly interchanged and have similar physical and chemical properties. Although not common to all radar systems, one such material is the silicate ester dielectric coolant used in many different aircraft electronic radar systems. Weather and environmental conditions, which can be closely related to the mission, can dictate different materials to be used. Trade-offs in performance in the selection of one material over another due to flammability properties, cold-temperature start-up capability and rust inhibition properties dictate what each military branch uses as a coolant fluid in their specific applications.

The information provided highlights some of the problems that both the US Air Force and Navy have experienced with silicate ester dielectric coolants and the advocacy for a more reliable and stable new PAO fluid.

This report, along with attachments, describes some of the in-depth testing and evaluation of the PAO within the laboratory, electronic component testing at the benchtop level, and flight test validation programs. These evaluations have been performed at the Air

Force Materials Laboratory, Naval Air Development Center (NADC), and several electronic radar component contractors. Also included are summaries of flight test validation programs performed at McConnell Air Force Base, Nebraska and Naval Air Test Center in Patuxent River, Maryland.

## 2. LABORATORY EVALUATION AND ASSESSMENT

Several critical requirements of a dielectric coolant must be met to provide a cooling medium for electrical components operating at high temperatures and high electrical stresses. In assessing a number of possible replacement candidate materials, a careful assessment was made to ensure that any recommended candidate met or exceeded the physical and electrical properties of the existing fluid. Equally important, the replacement material had to be compatible with existing electronic component materials and preferably with the existing fluid.

After an extensive screening of candidate fluids from several oil company suppliers by the Navy and a laboratory evaluation approach by the Air Force, the PAO hydrocarbon emerged as the best replacement candidate. Specific details of each approach have also been documented (1). Extensive laboratory analysis by the US Air Force Materials Laboratory and NADC confirmed that the PAO properties were equal to or better than typical silicate ester properties with the exception of the kinematic viscosity, lubricity, and flash and fire points. The physical properties generated for PAO and compared with respective US Air Force and Navy radar coolant property requirements are presented in Tables 1 and 2. The respective using engineer must decide if coolant systems can pump the slightly lower viscosity PAO fluid. The flash and fire-point differences requires an assessment by the using engineers as to the ignition source threats present in each application. The only notable discrepancies involved the viscosity characteristics of the PAO at -54°C. This observation was only relevant to the Air Force requirements due to deployment of aircraft in cold and harsh northern tier Air Force Bases. The relevance of this requirement will be addressed in further sections of this report.

The main attribute of the PAO material as the candidate replacement material for silicate ester fluids was the hydrolytically stable nature of the PAO material. The results of the degradation of silicate ester fluids as highlighted above is a direct result of fluid breakdown due to hydrolysis of silicate ester-type fluids (1). The hydrolysis process of silicate ester fluids is illustrated in Figure 1. The overall reaction process follows as the tendency of the -Si-OR bond towards hydrolysis and to form -Si-OH and R-OH. The -Si-OH product corresponds to the silica gel-type substance found in contaminated fluid. The other R-OH formed is the alcohol by-product which lowers the flash point of the fluid and presents an increased safety risk.

In more recent times, specific systems within the US Air Force and Navy have verified the existence and potential safety hazards associated with use of the hydrolytically unstable silicate ester. These systems, and problems identified, will be presented later in this report.

As stated above, several properties were critical when assessing the new PAO material as a replacement for silicate ester fluids. These properties have been condensed and presented in Table 3. The properties which have been marked by asterisk (\*) indicate where

the PAO material offers critical improvement over the silicate ester fluids. These improved properties and potential overall benefit for system performance criteria have been verified by a number of electrical component manufacturers (2,3). The proposed benefit of these improved PAO characteristics will be highlighted further in this report.

After thorough assessment and evaluation of this candidate replacement fluid by both the US Air Force and Navy laboratories, it was concluded that the PAO fluid offered significant and improved physical properties over the silicate ester fluids. Upon reaching these conclusions, the Air Force radar systems office (ASD/RWNA) initiated a program with the Hughes Aircraft Company to fully evaluate the PAO fluid in a side-by side manner with the silicate ester fluid in a full up radar systems compatibility test. Hughes is a radar systems manufacturer for a number of US electronic radar units. The fluids were fully evaluated in an APG-63 radar transmitter which is used specifically in the F-15 aircraft.

The Hughes Final Report, an extensive and thorough study of the two fluids, concluded that the PAO is an advantageous replacement fluid for the silicate ester (Coolanol 25R) fluid. The only notable limitation of the PAO material was the uncertain cold start capability of the fluid at -54°C. Hughes concluded that warm-up specification time should be reviewed and compared to actual field cold-starts. The Conclusions/Recommendations summary is included with this report (2). The full report, an extensive 286 page report, can be provided upon request.

In a separate contractor assessment program, Texas Instruments conducted a notable independent study on the feasibility of using PAO in radar transmitters. TI performed several additional physical property characterizations, as well as testing of material and component compatibility, flammability, dielectric strength, toxicity, miscibility with other fluids, air and water content, and foaming characteristics. TI assessment applies to Texas Instruments APS-116 and APS-137 transmitters and the report concludes with an overall summary recommendation that PAO may be utilized as a replacement fluid for silicate-ester and silicone fluids in radar transmitters(3). It should be noted that TI has been acknowledged by both the US Air Force and Navy command offices for their superior, no cost-to-the-government PAO study to improve and modernize US military equipment.

These specific independent laboratory studies and assessment programs provided an initial endorsement of the PAO material as a viable and promising replacement candidate for silicate ester fluids. The following section will highlight some more recent silicate-ester related field problems, systems affected, and the initiation of PAO flight tests and changeover in these problem-related systems.

### **3. US FIELD PROBLEMS AND FLIGHT TESTS**

Although the silicate ester problems have occurred for the last twenty years, a recent report of field maintenance problems encountered on the US Air Force's B-1B fleet initiated a more aggressive approach to solving the problems.

In mid-1988, the USAF Materials Laboratory received reports from B-1B aircraft field engineers that excessive and costly procedures were required to maintain avionic cooling systems. Field engineers reported that contamination in the form of a white gel-like

substance was prevalent throughout the avionic cooling system and was conglomerating on system filters. These deposits reportedly restricted flow and thus posed a safety of flight situation. To solve these problems, aircraft maintenance crews were constantly required to flush and fill the avionic systems to achieve system cleanliness and maintain system reliability. As an illustration as to the magnitude of the maintenance logistics, the B-1B aircraft utilizes approximately 70 gallons per aircraft. The cost of this constant system replenishment and actual fluid cost (\$80-\$100US per gallon) was excessive.

USAF Materials Laboratory personnel then investigated the reported findings by analyzing fluid samples from several aircraft suspect to be encountering problems. It was concluded from these analyses that fluid had indeed degraded due to hydrolysis of the silicate ester fluid. Sample fluids were found to contain various amounts of silica gel (containing silicon) and fluid flash points that were below the minimum acceptable safety level. The system engineers from the responsible user command office (Strategic Air Command) decided to sample the entire fleet of B-1B aircraft to determine the extent of the problem. It was concluded that contamination was widespread, and based on the recommendation of the Materials Laboratory, SAC would review the possible replacement of Coolanol 25R with PAO.

In November 1988, SAC decided that, based on all the laboratory and contractor data available, they would conduct a five-aircraft, six month flight test to evaluate fully the PAO fluid. The Materials Laboratory monitored the flight test by sampling the condition of the fluid at weekly and monthly intervals throughout the duration of the flight test. Fluid changeover was accomplished by flush and fill procedures with monitoring of percent changeover from silicate ester to PAO by gas chromatography. Critical properties monitored throughout flight test included: viscosity, flash point, acid number, water content, and silicate ester/PAO mixture ratio. It should be noted that specific details have not been provided due to amount of detail relative to the scope of this report. They can be provided upon request.

A successful flight test on the B-1B was completed in July, 1989 with no discrepancies or malfunctions encountered. Two of the five test aircraft were flown with approximately 60/40 PAO/silicate ester mixtures to determine the effect, if any, on system performance and to verify the miscibility of the two fluids. Questions relevant to the increase in viscosity at -54°C were dispelled due to infrequency of these low extreme temperatures and reduced operating capabilities of other related systems at these temperatures. Upon completion of this flight test, SAC officials have endorsed the performance and enhancement of the PAO fluid in the B-1B aircraft and in October, 1989 the decision was made to convert the entire fleet to PAO. Projected life-cycle cost savings of conversion to PAO on the B-1B entire fleet estimated at 947 million US\$ (SAC estimation).

In an effort to assess the potential problems within both the Air Force and Navy, several joint meetings were held to determine if problems were occurring throughout both services. Plans were developed to determine which aircraft used radar coolants, and problems encountered (if any), and to assess the technical and logistic feasibility of a PAO switchover for DOD. Results from a field survey determined that approximately 25 aircraft and missile systems were using or planned to use some type of silicate ester coolant. The systems identified are included in Table 4.

The US Navy took a renewed look at the past problems and reviewed reports of excessive maintenance on various aircraft radar units. Past findings revealed that the Navy F/A-18 and F-14 were subject to reduced flashpoints and reported cases of "black plague" (formation of black and gray solid particles) in the radar transmitter unit. Upon noting these problems and following the successful flight test in the B-1B, the Navy decided to conduct a flight test utilizing the PAO in the F/A-18. To date, six aircraft have completed a full system testing of PAO in the F/A 18 AN/AWG 65 radar. Specific details of this flight test evaluation are included in a briefing which was presented to the Air Force in November, 1989 (4). This successful flight test has also confirmed the laboratory and contractor data which had indicated that PAO is a viable replacement fluid for silicate ester fluids.

These more recent PAO assessment programs have provided the services with adequate information as to the decision for an overall systems applicability. Through the data generated, each aircraft system identified as using a silicate ester fluid has begun an individual program to assess the potential replacement of these fluids in their respective systems.

#### 4. PAO TRANSITION

Currently in the US DoD an effort is underway to assess and determine a logistic and operational approach to replace silicate ester coolants where viable and applicable. A systematic approach to this transition has been initiated whereby each specific system evaluates the feasibility of replacement through data generated both within the laboratory and through completed flight test programs. It is to be noted that PAO must be completely evaluated in each different radar system and cannot to be construed as a blanket replacement for all applications.

To date, several milestones have been achieved in this proposed replacement program. They are highlighted in Table 5. These events have provided the necessary direction and assistance to engineers to assess and decide on future switchover programs. To assist in these proposed programs, the Materials Laboratory has also generated a data bank for all relevant and pertinent information relating to changeover programs.

The PAO replacement effort has generated several beneficial features over the silicate ester-type fluids which has led to a broad interest in replacement efforts. These features are presented in Table 6. These attributes have been assembled as part of the overall benefit to radar system performance. They are also used in life cycle cost assessments. In addition, recent indications from Monsanto Corporation, which is the major supplier of Coolanol products (specified to MIL-C-47220), has indicated that they will no longer manufacture the Coolanol product line unless the US government subsidizes a plant relocation. Under these circumstances, the other silicate ester manufacturer, Chevron International, would become sole source supplier.

Relevant to actual PAO fluid suppliers, a concentrated effort to ensure adequate suppliers of the new PAO fluid has also been made. A fluid specification covering the PAO material, MIL-C-87252, has been issued and widely distributed throughout industry and the services (5). Presently, three different commercial suppliers have provided fluids conforming to the MIL-C-87252 specification. Relevant information may be provided upon request.

## 5. CONCLUSIONS

Current efforts within the US DoD to replace silicate ester dielectric coolants with a new PAO fluid have been highlighted. The PAO fluid offers a more reliable, maintainable and cost-effective alternative to current silicate ester and silicone fluids in radar systems.

Several improved properties of the PAO also offer a substantial cost savings in the form of reduced monitoring of fluid condition, longer and less complex storage conditions for fluid, and reduced maintenance of radar units at overhaul intervals. Furthermore, availability of current silicate ester fluids may diminish in the future due to streamlining of sole source supplier operations.

For the numerous beneficial features highlighted above and in the following attachments, it has been determined that the PAO fluid is an enhanced and viable replacement for silicate ester and silicone fluids used in military electronic radar units. Further flight testing and other future flight test verification programs should provide additional information on other comparable systems.

It is likely that the US experience with radar coolant in F/A-18 and Orion P3 aircraft can be directly extrapolated to Australian conditions. Concern with the higher viscosity of PAO fluid at -54°C is less significant for Australian environmental conditions.

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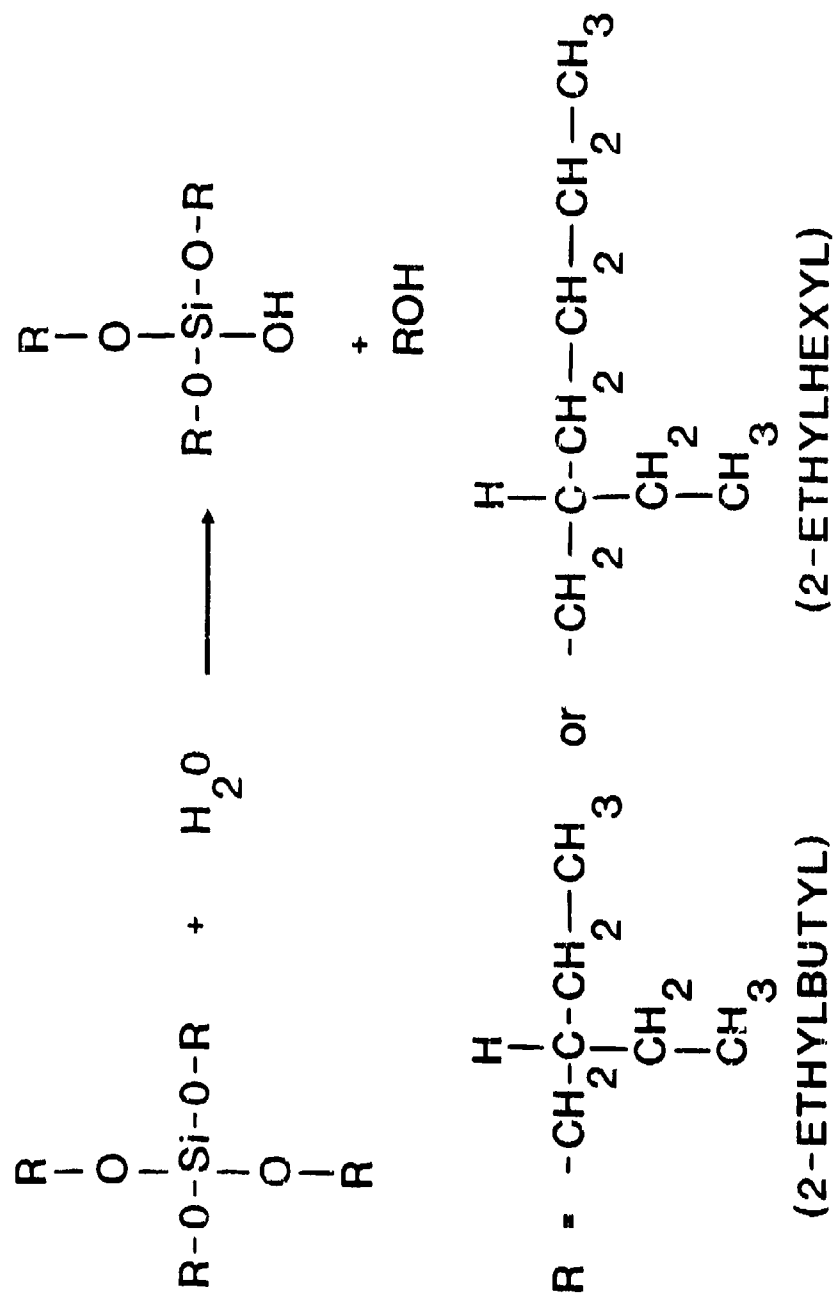


Figure 1.  
HYDROLYSIS REACTION OF SILICATE ESTERS

**Table 1. USAF PROPERTY REQUIREMENTS AND COMPARISON OF PAO  
COOLANT/DIELECTRIC FLUID**

| Property  | Requirement              | Polyalphaolefin<br>Candidate Fluid                   |
|---|--------------------------|--|
| Kinematic Viscosity (cSt)<br>38°C (100°F)<br>99°C (210°F)         | 6.6-7.0<br>2.2-2.3       | 5.7<br>1.8   |
| Dielectric Strength, 0.10-in gap @ 25°C (KV)                      | ≥35                      | 44   |
| Flash Point, Open Cup °C(°F)<br>Fire Point, °C(°F)                | ≥188 (370)<br>≥221 (430) | 162 (325)<br>176 (350)                               |
| Water Content (%)   | ≤0.05                    | 0.0008   |
| TYPICAL PROPERTIES  |                          |  |
| Specific Heat (cal/gm/°C)   | ≥0.48                    | 0.53   |
| Thermal Conductivity (cal-cm/s-cm <sup>2</sup> °C)                | ≥3.2 x 10 <sup>-4</sup>  | 3.03 x 10 <sup>-4</sup><br>to 3.4 x 10 <sup>-4</sup> |
| Neutralization No. (mg KOH/gm)                                    | ≤0.20                    | <0.1   |
| Average Coefficient of Thermal Expansion<br>-51° to 149°C (°C)    | ≤0.00026                 | 0.00026  |
| Specific Gravity  | ≤0.880                   | 0.79   |
| Corrosion-Oxidation Stability<br>168 hours, 121°C                 |                          |  |
| Weight Change (mg/cm <sup>2</sup> )                               |                          |  |
| Al  | ≤0.1                     | +0.01  |
| Cu  | ≤0.1                     | -0.03  |
| Steel   | ≤0.1                     | -0.02  |
| Cd  | ≤0.1                     | -0.01  |
| Mg  | ≤0.1                     | +0.02  |
| Ti  | ≤0.1                     | 0.00   |
| Fluid Viscosity Change (%)  | ≤1                       | 2.3  |
| Neutralization No. Increase (mg KOH/gm)                           | ≤0.1                     | 0.0  |
| Lubricity, Scar Diameter (mm)<br>52100.52100, 1 hr, 75°C, 600 rpm |                          |  |
| @ 4 kg  | ≤0.40                    | 0.54   |
| 10 kg   | ≤0.50                    | 0.60   |
| 40 kg   | ≤1.00                    | 0.93   |

**Table 2. US NAVY PROPERTY REQUIREMENTS AND COMPARISON OF  
PAO COOLANT/DIELECTRIC FLUID**

| Property  | Requirement  | Polyalphaolefin<br>Candidate Fluid |
|---|--|------------------------------------|
| Kinematic Viscosity (cSt)@                            |  |                                    |
| -40°C (-40°F)   | ≤ 275  | 273                                |
| -18°C (0°F)   | ≤ 27   | 52                                 |
| 38°C (100°F)  | ≤ 4.50   | 5.3                                |
| 99°C (210°F)  | > 1.5  | 1.7                                |
| Dielectric Strength, 0.10-in gap @ 25°C (KV)          | ≥ 35   | 38.5                               |
| Volume Resistivity, @ 25°C (ohm-cm)                   | ≥ 10 x 10 <sup>10</sup>  | 3.4 x 10 <sup>12</sup>             |
| Dielectric Constant (100 Hertz @ 25°C)                | ≤ 2.8  | 2.08                               |
| Power Factor (10 <sup>6</sup> Hertz @ 25°C)           | ≤ 0.008  | 0.004                              |
| Flash Point, Closed Cup °C(°F)                        | ≥ 118 (245)  | 154 (310)                          |
| Autoignition Temperature °C (°F)                      | ≥ 249 (480)  | 332 (630)                          |
| Specific Heat (cal/gm°C)                              |  |                                    |
| -40°C (-40°F)   | ≥ 0.373  | 0.48                               |
| 25°C (77°F)   | ≥ 0.44   | 0.53                               |
| 149°C (300°F)   | ≥ 0.580  | 0.65                               |
| Thermal Conductivity (cal-cm/s-cm <sup>2</sup> °C)    |  |                                    |
| -40°C (-40°F)   | ≥ 3.5 x 10 <sup>-4</sup>   | 4.5 x 10 <sup>-4</sup>             |
| 149°C (300°F)   | ≥ 2.8 x 10 <sup>-4</sup>   | 3.4 x 10 <sup>-4</sup>             |
| Neutralization No. (mg KOH/gm)                        | ≤ 0.10   | 0.03                               |
| Coefficient of Thermal Expansion<br>(cc/cc°C)         | ≤ 0.0011   | 0.00027                            |
| Specific Gravity @<br>25°C (77°F)                     | 0.888 to 0.900   | 0.809                              |
| Vapor Pressure @ 149°C (300°F) (Torr)                 | ≤ 1.5  | 9.2                                |
| Pour Point °C(°F)                                     | ≤ -82 (-80)  | -68 (-90)                          |
| Rubber Swell (%)                                      |  |                                    |
| MIL-R-6855, Class II, Grade 60<br>70°C (158°F), 168 h | 0 to +7.5  | + 0.8                              |
| Thermal Stability<br>@ 177°C (350°F) 100 hours        | Viscosity increase @<br>40°C (104°F) ≤ + 5%                              | +0.42%                             |
| Water Content (ppm)                                   | ≤ 100  | 50                                 |
| Low Temperature Storage                               | No gelling<br>crystallization or<br>or solidification @ -40°C (°F) 96 hr | Pass                               |

**Table 2.-cont'd-US NAVY PROPERTY REQUIREMENTS AND COMPARISON  
OF PAO COOLANT/DIELECTRIC FLUID**

| Property   | Requirement   | Polyalphaolefin<br>Candidate Fluid |
|--|---|------------------------------------|
| <b>Corrosion-Oxidation Stability</b>                   |   |                                    |
| 168 hours, 135°C                                       |   |                                    |
| <b>Weight Change (mg/cm<sup>2</sup>)</b>               |   |                                    |
| Steel  | ≤0.2  | -0.003                             |
| Cd   | ≤0.2  | -0.048                             |
| Al   | ≤0.2  | -0.016                             |
| Zn   | ≤0.2  | -                                  |
| Cu   | ≤0.4  | -0.04                              |
| Fluid Viscosity Change (%) @ 40°C                      | ≤5  | 1.3                                |
| Neutralization No. Increase (mg KOH/gm)                | ≤0.5  | 0.03                               |
| <b>Lubricity, Scar Diameter (mm)</b>                   |   |                                    |
| 52100.52100, 1 hr, 75°C, 600 rpm                       |   |                                    |
| @ 4 kg   | ≤0.60   | 0.17                               |
| 10 kg  | ≤0.70   | 0.25                               |
| <b>Particulate Contamination per<br/>100-ml Sample</b> |   |                                    |
| <b>Particle Size</b>                                   |   |                                    |
| 10-200 micrometers                                     | <14,000   | 12,280                             |
| 200 micrometers  | < 30  | 0                                  |
| Figure of Merit 38°C (100°F)                           | 0.19  | 0.21                               |
| Miscibility  | Miscible in All Proportions<br>with Silicate Ester Fluids | Pass                               |

Table 3. CRITICAL PROPERTIES FOR A  
HIGH PERFORMANCE FLUID

| <u>PHYSICAL</u>       | <u>MATERIAL</u>  | <u>ELECTRICAL</u>   |
|-----------------------|------------------|---------------------|
| VISCOSITY/TEMPERATURE | COMPATIBILITY    | DIELECTRIC STRENGTH |
| THERMAL STABILITY     | SYSTEM MATERIALS | RESISTIVITY         |
| FOAMING TENDENCY      | EXISTING COOLANT | POWER FACTOR        |
| FLASH POINT STABILITY | LUBRICITY*       |                     |
| HYDROLYTIC STABILITY* |                  |                     |
| HYGROSCOPIC TENDENCY  |                  |                     |
| DENSITY               |                  |                     |
|                       |                  | <u>OTHER</u>        |
|                       |                  | COST*               |
|                       |                  | COMMERCIAL AVAIL-   |
|                       |                  | ABILITY*            |

# Table 4. RADAR SYSTEMS USING COOLANT

| <u>USAF</u>    | <u>USN</u>           | <u>WEAPONS/OTHER</u> |
|----------------|----------------------|----------------------|
| B-1B*          | F-14                 | PAVE                 |
| F-15           | F/A-18*              | LANTIRN              |
| F-16           | S-3                  | SPIKE                |
| EF-111         | P-3*                 | ALQ-119 POD          |
| EC-130         | E/A6B                | PHEONIX              |
| E-3A           | AV-8B                | GROUND RADAR - ARMY  |
| B-2            | NATF (PROPOSED)      | MISSILE SYSTEMS-ARMY |
| ATF (PROPOSED) | LRCCA P-7 (PROPOSED) |                      |
| F-117          |                      |                      |

\*PAO conversion evaluated

**Table 5. MILESTONES IN US PAO  
REPLACEMENT PROGRAM**

- 1970'S PROBLEM APPARENT - US NAVY
- 1974 PROBLEM MONITORED
- 1979: 70% OF AVIONICS FOUND CONTAMINATED - NAVY
- 1979-81: AIR FORCE ENCOUNTERS PROBLEM WITH COOLANOL 40
- 1985 NUMEROUS SYSTEMS IDENTIFIED PROBLEMS - F4,F-15,F-16
- 1986: USAF/ASD PROGRAM - HUGHES STUDY: F-15, F-14
- 1987-89: B-1B PROGRAM (PROBLEMS AND CONVERSION)
- 1987-88: P-3 PROGRAM (NAVY/TEXAS INSTRUMENTS)
- 1988-PRESENT: F-14/F/A-18 FLIGHT TEST/CONVERSION (NAVAIR)
- 1989: BROAD TRANSITION ASSESSMENT - ALL SYSTEMS

## Table 6. PAO KEY FEATURES

- HYDROLYTICALLY STABLE
- BETTER HEAT TRANSFER
- BETTER LUBRICITY
- LESS FOAMING
- AVAILABILITY
  - PAO'S MADE FROM READILY AVAILABLE ETHYLENE
  - 3 APPROVED SOURCES
  - PAO AVAILABLE AT LOW COST \$15US/GAL VS \$80-100US/GAL FOR COOLANOL
- HANDLING
  - LOW TOXICITY AND EASILY DISPOSED
  - RECYCLING/RECLAMATION - NOT PRACTICAL
  - FLUID LESS HYGROSCOPIC

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